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DISCUSSION AND CORRESPONDENCE

WHEN IS A FORCE NOT A FORCE?

In his communication to Science for March 16, 1917, Mr. A. H. Patterson very pertinently calls attention to the vagueness, lack of precision and error in the treatment of the force concept by current physics text-books. Much of Mr. Patterson's criticism deals with Newton's third law of motion and appears to be based on a misinterpretation of that law. To this I wish to call attention.

Force is always exerted by one portion of matter, A, upon a second portion of matter B. These may be distinct bodies or parts of the same body. If A exerts a force on B then, the third law tells us, B exerts an equal force in the opposite direction on A. If the force of A on B *is* called the action, the force of B on A is called the reaction. The action and reaction do not act on the same body or body-part. Failure to fully appreciate this seems to be responsible for the present as well as many other misinterpretations of the third law.

Mr. Patterson asks: "What is a student to think when he is told that to *every* action there is *always* an equal and contrary action, and is then informed that (only) an unbalanced force acting on a mass produces acceleration?" The two statements are mutually consistent and true. In order to safeguard the student against some of the pitfalls which are dangerous even to his teachers it is only necessary to make the information more complete.

Mr. Patterson's problems may well serve this purpose. The ball at the end of a rubber band is the first of these. Let us ignore the effect of gravity. When the ball is whirled about in a circular path at uniform speed the pull exerted by the rubber band *on the ball* is called the centripetal force. No other balanced force and gives rise to an acceleration which manifests itself in the change in direction of the velocity. The equal and contrary action is the outward pull of the ball *on the string,* known as the centrifugal force. The string is not accelerated because the pull of the support at the fixed end is equal and opposite to the centrifugal pull at the free end. The forces on the string are balanced.

A porter pushes a truck at uniform speed over level ground. Then the force which he exerts forward on the truck is equal to the backward frictional force. If this frictional resistance were suddenly to vanish, the forward force exerted on the truck by the porter would be the only horizontal force, hence unbalanced and a forward acceleration would result. Both with and without friction the truck pushes backward on the porter with an equal force. In addition to pushing forward on the truck the porter is pushing backward on the ground with his feet, and consequently the ground is pushing him forward. If the forward push of the ground and the backward push of the truck are equal the forces on the porter are balanced and he moves without acceleration. Everywhere the forces act in pairs, because there must be an exerter of the force and a body on which it is exerted. Newton's law has a meaning only when both bodies are considered.

Newton's third law requires no distinction between inertia-reactions and other forces. To introduce them serves to complicate rather than to simplify. The following problem utilizes Mr. Patterson's method, quoting freely from the closing paragraphs of his communication.

A mass M rests on a perfectly smooth horizontal surface. To M we apply a horizontal force F. Being the only horizontal force it is unbalanced. It is opposed by an inertia reaction *which can in a sense balance it, but can not hold it in equilibrium because a force opposed only by inertia reaction always produces acceleration.*

It is difficult to see the need of this devitalized form of the third law, either from the point of view of principle or of practice. Forces do always exist in pairs, yet the forces on either or both of two bodies between which force-action exists may be unbalanced.

Mr. Patterson assumes a contradiction where none exists and then proposes an artificial way out.

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THE THIRD LAW OF MOTION AND "INERTIA REACTION"

The recent article by Mr. Andrew H. Patterson in Science for March 16, 1917, impels me to add to the discussion of questions in mechanics something that I have tried to make clear to students. It is along the line of Mr. Fulcher's article of November 24, and concerns the confusion between the third law of motion, the second law, and D'Alembert's principle.

Mr. Patterson appears to object to teaching that "to every action there is always an equal and contrary action" or that "forces always occur in pairs" and at the same time that an "unbalanced force" produces an acceleration. There is surely no inconsistency in this, since the "pairs" of forces or the action and reaction act on different bodies, say A and B, then if no other bodies are acting upon them, there will be an unbalanced force on each, and each will be accelerated, but in opposite directions. Evidently another pair of forces may act between B and C such that on the whole the forces on B exactly balance, and yet A will be left with an accelerated motion. On the other hand, while it is clear from writing the equation representing the second law of motion in the form $F - Ma = 0$, that *if* a force equal to the mass times the acceleration *should* act on the body in the opposite direction to the impressed force, these forces would be in equilibrium, this is not a case of the third law, which specifies that the forces considered act between two bodies and not on one and the same body. If for a system one adds the idea (D'Alembert's principle?), that the internal actions and reactions of any system of bodies are in equilibrium among themselves, a special case of the third law, one obtains the more general statement that *if* forces equal to the several masses times their respective accelerations *were* applied, etc., a form which is useful in the handling of problems, but which does not imply that such forces *are* acting and does not call for the idea of "inertia reactions."

The case where "inertia reaction" is most frequently drawn in, in connection with action and reaction is the instance of an object being whirled around on the end of a string. Now when one explains the motion of the moon about the earth as due to the action of the gravitational force on the moon directed towards the earth, one looks for the "reaction" in a gravitational force on the earth directed toward the moon, but not a force on the moon, and this reaction on the earth has nothing to do with the mass $\times$ acceleration of the moon, but would be the same if the moon were at rest in the position which it has at any instant. Is not the same true for the ball and string? Consider the case where a person grasps the ball by a hook at the end of a diameter, and pulls on a cord at the other end with the force F, the ball as well as the cord is strained, and we may say that the ball is pulling on the string and the string on the ball (the third law), in virtue of this strain. Now let go at the one end, in order to continue to apply a force F the hand must be moved with the same acceleration which the ball has in order to keep the string stretched, and would not the ball in the neighborhood of the string remain strained as before and hence the forces between ball and string be of the same nature as before? Now suppose the ball swung around the head, as Mr. Patterson suggests, would not the ball still remain strained and would it not pull on the string with a force which would be exactly the same as if the ball were at rest, but in the same state of strain? If so why bring in an inertia reaction? In the illustration of the porter pushing a cart, as long as he *actually pushes* there is an equal counter force *on him*, but in the one case the push on the cart may be balanced by friction, and in the other it would be an unbalanced force on the cart. Actually if friction suddenly ceased would not the porter probably notice that the force with which he was pushing had suddenly diminished, and